Adaptive Sampling in a Research Observatory During the Shallow Water 2006 Acoustics Experiment

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LONG-TERM GOALS

Develop and demonstrate in a collaborative Mid-Atlantic Bight test-bed a coupled observation and data assimilative modeling capability that contributes to our understanding of continental shelf processes, provides societal benefits, and is relocatable worldwide in both collaborative and non-collaborative environments. Our approach will leverage the complementary capabilities of academic, industry and government groups through NOPP-style partnerships to develop new satellite remote sensing algorithms, new HF radar hardware and processing software, and new autonomous underwater vehicles and sensors for subsurface adaptive sampling. We will use the new technologies to sustain a continuous long-term presence in the Mid-Atlantic with enhanced coverage during an ongoing series of scientific process studies that include advanced data assimilation in coupled atmosphere/ocean physical, biological, biogeochemical, and sediment transport models. We will simultaneously develop and demonstrate the capability of a reach back cell to operate sustained autonomous ocean observing systems in remote locations world-wide.

OBJECTIVES

A) Prepare and deploy a fleet of gliders to occupy a series of closely spaced repeat transects across the shelf-slope front within and around the SW06 mooring array, maintaining a continuous presence for the full duration of the joint experiment.

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B) Distribute the glider CTD datasets in near real-time to the ocean modeling community for assimilation by forecast models.

C) Use the full resources of the New Jersey Shelf Coastal Observatory to support real-time shipboard operations in the SW06 region, emphasizing the detection and characterization of internal waves during the first half of the experiment and resolution of the sub-mesoscale variability of the shelf-slope front for acoustics applications during the second half.

D) Actively participate with other SW06 scientists in the collaborative post-analysis of SW06 dataset.

E) Use the SW06 dataset as the starting point for a Rutgers student's Ph.D. thesis.

APPROACH

Field work for SW06 was completed in the early fall of 2006. Subsequent efforts by field program participants shifted to data analysis, interpretation, and publication preparation. The initial focus has been on the processing, validation, interpretation and documentation of the Rutgers data sets so they can be shared with the SW06 scientific community in proposed follow-on studies.

WORK COMPLETED

Two techology validation papers and a series of science papers are in preparation. Kohut et al. is using the Coast Guard surface drifters deployed during SW06 to provide the first validation data for the long range coverage of the outer shelf by the CODAR HF Radar array. Gong et al.is using the resulting 5 year CODAR dataset to examine the average surface current patterns for different wind regimes, specifically examining the different cross-shelf transport patterns near the Hudson Shelf Valley. Kerfoot et al. is using the extremely strong summer 2006 thermocline to develop the speed–dependent thermal lag coorection to the glider CTD sensor. Gong et al. used the glider data to characterize the slope water salinity intrusions on the outer shelf. The cross-shelf exchanges studied by Donglai Gong in the CODAR and glider data constitute the first chapter of his thesis. Casteleo et al. then placed the summer 2006 experiment within the context of the longer term observations of the Tuckerton Glider Endurance Line. Bowers et al. conducted a sensitivity study to the model configuration and data inputs for the Tropical Storm Ernesto forecast and examined its impact on shelf currents, stratification and sediment resuspension. Glenn et al. expanded the storm study to the larger glider optical dataset to examine the relation between winds, currents, tides, waves, and sediment resuspension in storms. To date, three of these papers have been submitted for review.

RESULTS

High resolution 3-D glider sampling of the New Jersey outer-shelf (Figure 1A) revealed the complex nature shelf-slope exchange processes, in particular the salty slope water intrusions onto the continental shelf (Figure 1B). The depth-averaged currents along-shelf flow at 10 cm/s to the southwest at the outer-shelf, indicating a transit time of 7-10 days for the intrusion features through the NLIWI/SW06 study site. Given the glider sampling period was 2.5 days, this allowed multiple realizations of the observed hydrographic features in our sampling volume. Analysis of over 25,000 glider CTD casts identified four types of slope water salinity intrusions, surface, pycnocline, sub-pycnocline, and bottom intrusions (Figure 2A). The pycnocline intrusions inshore were affected by shelf stratification which was especially strong due to remnant of low density Hudson River water

associated with heavy June rainfall. Sub-pycnocline intrusions were possibly associated with the separation of the bottom boundary layer at the foot of the shelf-slope front with inshore diapycnal mixing below the seasonal pycnocline. The location of the foot of the shelfbreak front was correlated with alongshelf wind stress. Overall, the intrusions were persistent and highly variable in space and time, likely forced by offshore eddies. The pycnocline and the sub-pycnocline intrusions could each deliver approximately one-sixth of the slope water salt into the sampling volume, while bottom intrusions could deliver half, with the remaining portions being surface intrusions and unclassified slope water. Tropical Storm Ernesto, which passed through the New Jersey Shelf at the beginning of September dissipated and mixed away significant portions of the intrusions. Slope water intrusions however re-established themselves within a week. Low energy but persistent processes such as solar heating, southerly wind and slope water eddies were seen driving intraseasonal variabilities such as deepening of the pycnocline, transport of surface freshwater, and vertical movement of salt from the bottom layer to mid-depth near the shelfbreak. High energy episodic events such as storm mixing on the other hand was the catalyst for major seasonal shift in shelf hydrographic structure (Figure 2B). The large scale deployment of Webb gliders during the SW06 experiment enabled quantitative understanding of initiation, spatial distribution and dissipation of the highly dynamic shelf-slope exchange processes.

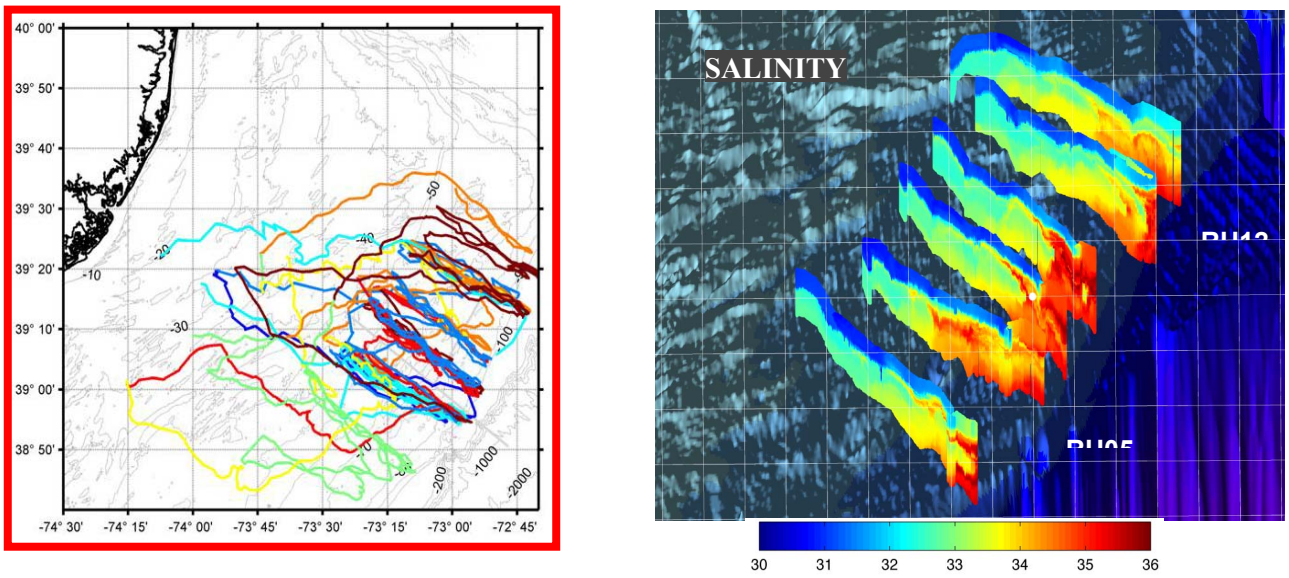

Figure 1. A. Track composite for 17 glider deployments during SW06. B. Salinity Intrusions revealed in a coordinated sweep across the shelf-slope front by 6 gliders.

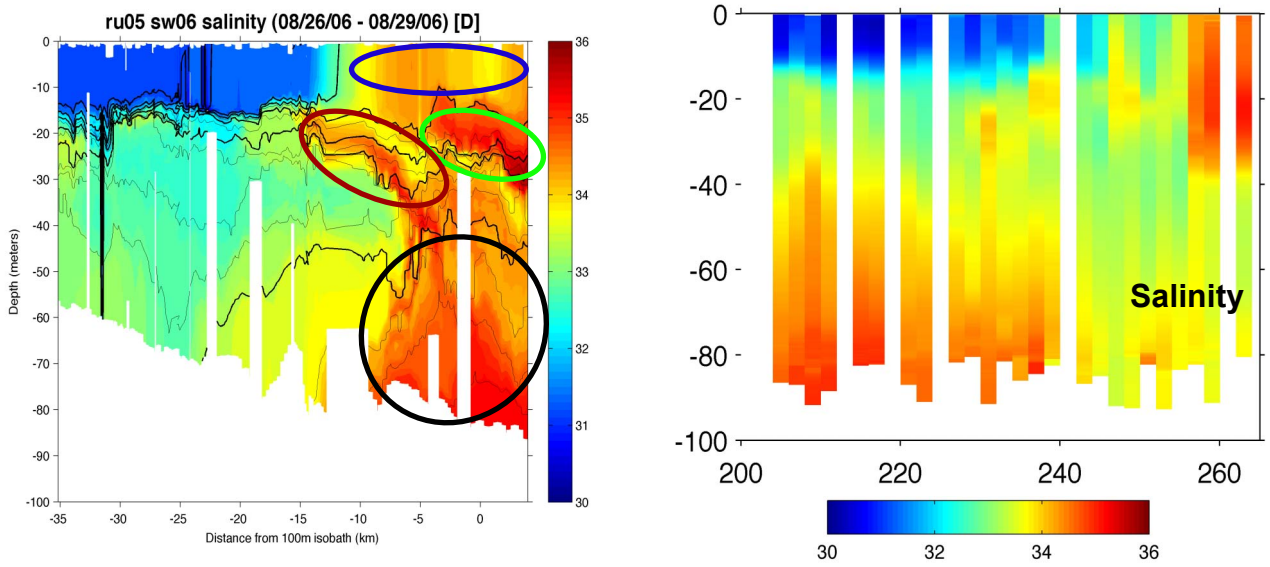

Figure 2. A. Salinity intrusions were identified as surface (blue), pycnocline (green), subpycnocline (red) and bottom (black). B. Time series of salinity at the outer shelf end of the main transect.

IMPACT/APPLICATIONS

Physical observations indicated the summer of 2006 was an anomalous year. An extreme warm core ring generated in the spring swept the area clean of typical Gulf Stream rings, limiting the impact of offshore eddy forcing to shelf break eddies. Persistent southerly winds produced strong upwelling fronts along the New Jersey coast and recurrent cross-shelf transport pathways along the Hudson Shelf Valley to the outer shelf, a previously under-appreciated process affecting the outer shelf. Record rainfall in the Hudson River watershed resulted in significant freshwater discharges that spread down the Shelf Valley, resulting in stronger than usual stratification over the outer shelf. These results provide motivation to further investigate the variability in the nonlinear internal waves and the salinity intrusions on the outer shelf in future years.

A new type of slope water intrusion was identified using the SW06 glider dataset (Figure 2, red region). It tends to develop just below the pycnocline (thus termed sub-pycnocline intrusion) with a base rooted in the bottom intrusions. It often exists significantly inshore of the canonical pycnocline intrusions. When projected in Density-Spiciness space, the sub-pycnocline intrusions appear denser and less spicy than the pycnocline intrusions. The observed vertical structure of these intrusions suggests secondary shelf circulation mechanisms playing a role in its formation. Tests for isopycnal mixing processes such as Bottom Boundary Layer detachment using the Accumulated Temperature Change (Pickart, 2000) method has yield partial explanation. A diapycnal mixing mechanism is required to explain its full structure. The quest for full dynamical understanding of the sub-pycnocline intrusion has motivated further modeling based analyses.

Due to its significant inshore extent and proximity to the surface mixed layer, the sub-pycnocline intrusion could play a significant role in the delivery of salt to the mid to outershelf. Tropical Storm

Ernesto showed that excess salt within the pycnocline was rapidly mixed in the surface layer during the storm's passage. Salt budget estimates within the SW06 sampling volume before and after the storm indicate that the pycnocline and sub-pycnocline intrusions delivered enough salt to account for the observed mean salinity increase of 1.5 in the surface layer.

TRANSITIONS

The glider formation flying used in SW06 was incorporated in the design of the glider flights for the Navy's 2007 Valiant Shield exercise. The success of keeping the oceanographer in the loop for glider mission planning motivated the development of the REMAP 3-D visualization software by the ONR Glider Consortium, resulting in a prototype that was used in the Navy's Glider Operations Center (GOC) during Valiant Shield.

The ability of a glider to tow a tail with an acoustic bioprobe attached was demonstrated during SW06 in a test conducted with URI. The glider was able to tow the tail across the shelf to the outershelf experiment site, motivating additional tests of a towed tails on gliders with URI and others.

The storm glider data from Tropical Storm Ernesto invigorated interest in turbulent mixing on the outer shelf, providing motivation for deploying an OSU turbulence sensor on a glider during the 2007 hurricane season, and the subsequent development of a proposal to construct a dedicated turbulence glider.

The highly successful Tropical Storm Ernesto forecasts during SW06 motivated a study of forecast sensitivity to a wide range of model parameters, indicating that for this tropical storm during its transition to extra-tropical, the path was highly dependent on the many subgridscale parameterizations available to the forecast model. The capability has been transferred to the local NOAA weather forecast office to improve their storm forecasts.

RELATED PROJECTS

The Mid-Atlantic Bight rapid environmental assessment Multidisciplinary University Research Initiative (MURI) will provide follow-on opportunities to develop and test advanced data assimilation techniques for coupled physical-biological models using physical datasets similar to those acquired during SW06 but expanded to include ocean color from satellites and in situ optics from gliders. Data assimilation experiments from SW06 indicated that glider sampling scheme that focused on resolving processes in the mooring array produced an excellent hindcast of the stratification in the immediate vicinity of the moorings, the desired result for the SW06 process studies. However, the limited spatial extent of the data relative to the forecastable mesoscale resulted in poor forecasts of the shelf wide flows. This prompted the MURI glider sampling strategy to begin testing the shelf wide glider flights that are now zigzagging along the shelf sweeping across the larger area with the mean flow from Cape Cod, MA to Cape May, NJ. The effect of this larger scale sampling on forecast skill is now being evaluated.

Lessons learned from SW06 experiment on the Mid-Atlantic's outer shelf are now being applied to glider sampling and forecasting activities associated with the Rapid Environmental Assessment MURI, and the recently funded Mid-Atlantic Bight Regional Coastal Ocean Observing System (MARCOOS). Both of these Navy and NOAA projects will in turn provide a larger scale context for the locally intensive NSF Ocean Observing Initiative Pioneer Array to be deployed on the Mid-Atlantic Bight

outer shelf. The enhanced activity on the Mid-Atlantic shelf provides a potential testbed for the Navy's Littoral Battle Space Fusion and Integration (LBSF&I) initiative, a program that is expected to purchase a large number of gliders for sustained environmental assessment in forward deployed areas with similar oceanographic conditions.

PUBLICATIONS

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